4.11 GEOLOGICAL RESOURCES/STRUCTURAL INTEGRITY REVIEW

The geology, seismicity and soil conditions at the Shell Terminal directly affect the structural integrity of the Shell Terminal. Section 4.11 describes the site geological setting and geotechnical conditions, and the Shell Terminal and trestle structures and their structural condition and integrity, identifies and describes geohazards that exist and could affect the Project facilities and appurtenant structures, assesses potential impacts of these hazards on the structures/facilities, and recommends measures to mitigate significant adverse impacts.

4.11.1 Environmental Setting

4.11.1.1 Geologic Setting

The Shell Terminal is located in Martinez (Contra Costa County) along the southern edge of the Carquinez Strait approximately 0.75 mile southwest of the Benicia-Martinez Bridge. Because the Shell Terminal is located in relatively protected waters, the primary design loads for its operation and stability are the berthing and mooring loads from tankers, and potential effects of earthquake forces and displacements on the structure.

The Shell Terminal is located in the seismically active San Francisco Bay Area. Moderate to severe earthquakes on any of the numerous faults in the area could impact the site. Of particular concern is the Concord/Green Valley Fault, which is located approximately 2.5 miles east of the site. The active Concord/Green Valley Fault is capable of producing an earthquake with a moment magnitude (Mw) of about 6.9.

Regional Geology

California is located on the boundary between the Pacific and North America tectonic plates. The Pacific plate comprises the entire northern Pacific Ocean, and the North America plate includes the remainder of the North American continent and the western half of the Atlantic Ocean. The North America plate is drifting southwesterly relative to the Pacific plate and overriding it. The main line of contact between these two plates is the San Andreas Fault system.

San Francisco Bay area lies within a geologically very active and dynamic part of the Coast Ranges geomorphic province of California, which is characterized by a series of nearly parallel mountain ranges (Goldman 1969). Active faults, including the Concord/ Green Valley, West Napa, Calaveras, Hayward, San Gregorio, and San Andreas Faults, are roughly parallel the western and eastern limits of the Bay. The Bay began forming during the Pleistocene Epoch, approximately 2 million years ago, when the San Francisco-Marin block began to tilt eastward along the Hayward Fault. The eastern side of the block became a depression and filled with sediment and water.

The bedrock units underlying the area east of the Hayward Fault range from Jurassic-Cretaceous to Quaternary age (approximately 135 million years old to recent). The oldest unit is called the Franciscan Formation. This formation probably originated on the Pacific Ocean floor and was welded to the western margin of the American continent by plate movement. Subsequently, it was pushed upward through the younger sedimentary rock to form the backbone of the Diablo Range (Contra Costa County 1975). The strata of this bedrock formation are highly distorted and partially metamorphosed through heat and compression. The Franciscan Formation primarily consists of interbedded sandstone and shale, limestone, radiolarian chert, and metavolcanic rocks (Goldman 1969).

The next oldest bedrock formation in Contra Costa County is the Great Valley Sequence, a thick sequence of Tertiary age sandstones and shales that overlies the Franciscan Formation. The Great Valley Sequence is sedimentary rock formed under ancient seas that once existed on the American continent. The youngest consolidated (hard) rock is the group laid down during the geologic age known as the "Tertiary". This unit is largely sedimentary rocks not yet hardened as have the older units. The youngest surface formations are the deposits of Quaternary-age marine sediments known as "bay mud". Figure 4.11-1 depicts the regional surface geologic conditions of the Suisun Bay and Carquinez Strait region near the Project site.

Site-Specific Geology

Site-specific characteristics of the underlying geologic conditions described in this section are based on the regional studies of the Bay conducted by the California Geological Survey (CGS) formerly known as the California Division of Mines and Geology (CDMG) (Goldman 1969; Treasher 1963), and site-specific geotechnical investigations conducted during the development of the Shell Terminal and Refinery facilities (Frederic R. Harris, Inc., 1964).

At the Shell Terminal, the local surface conditions are primarily marsh/wetland deposits along the southern shoreline of the Carquinez Straits and the river sediments beneath the Strait at the Shell Terminal wharf. The sediments that overlie the bedrock (described in the previous section) consist of Pleistocene alluvium and late Quaternary-age (Holocene) bay mud. During late Pleistocene and Holocene time, the sea level fluctuated several times. Lower elevation areas were exposed and subsequently submerged during changes in sea level, allowing for the deposition of the young bay mud. Young bay mud is of Holocene age (less than about 11,000 years old), and consists of gray silty clay typically very soft-to-soft in the upper portions of the profile and semi consolidated (firmer/stiffer) in the lower portions.

Goldman's (1969) contour maps of the top of bedrock suggested that the top of bedrock lies approximately 90 feet below MLLW near the Shell Terminal shoreline beneath the Shell Terminal trestle to approximately 120 feet below MLLW along the Shell Terminal wharf.

Figure 4.11-1 – Surface Geology

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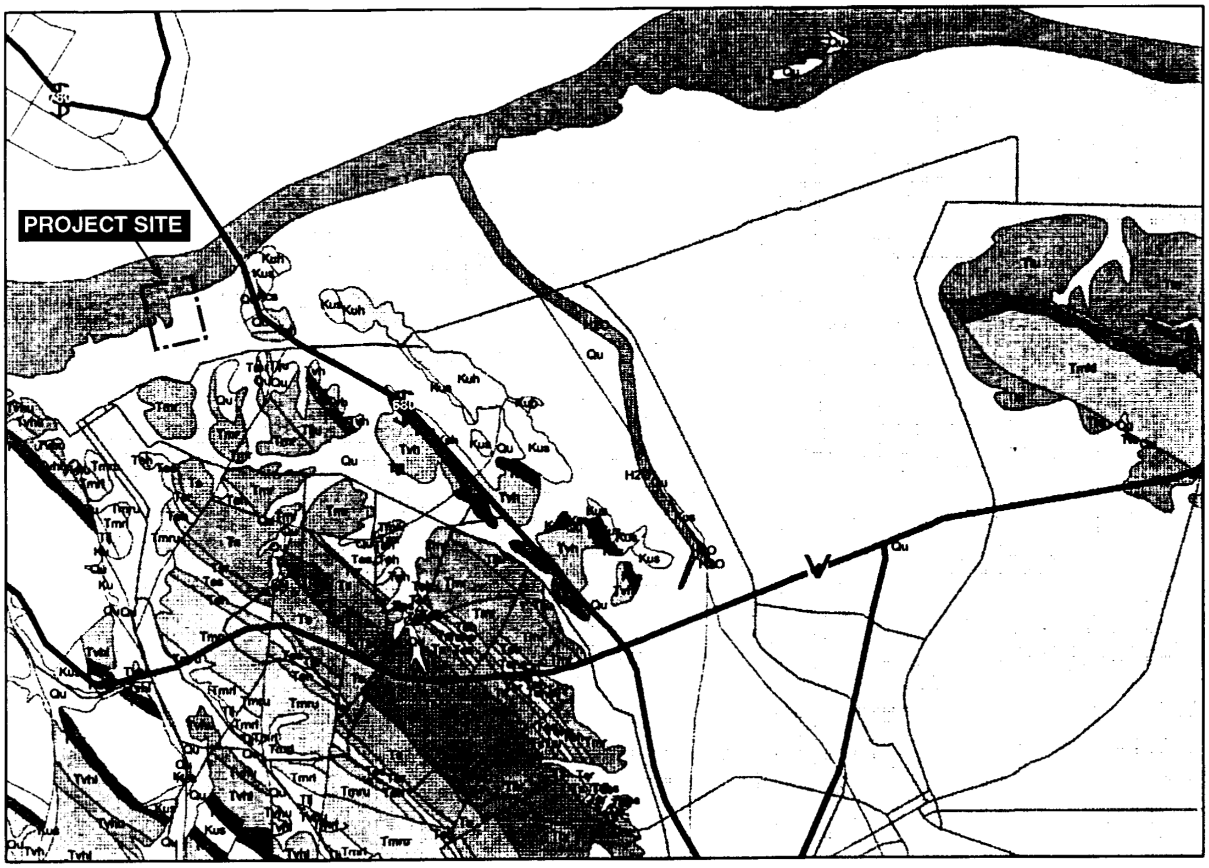
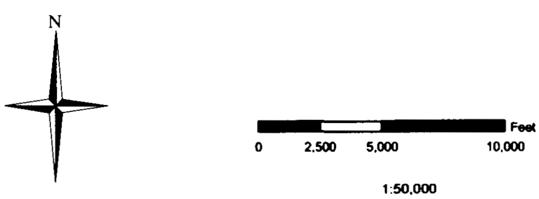


Source: "Preliminary Geologic Map Emphasizing Bedrock Formations in Contra Costa County, California: A digital Database," Compiled by R.W. Graymer, D.L. Jones, and E.E. Brabb, (USGS OFR 94-622)



Legend

- Kcs - Gray, massive quartz arenite
- Tljl - Lower member. Sandstone.
- Tlju - Upper member. Shale.
- Qu - Surficial deposits, undivided (Pleistocene and Holocene)
- Kus - Sandstone, siltstone, and shale
- Kuh - Massive sandstone, minor siltstone
- Ksh - Siltstone and shale
- Tmr - Muir Sandstone of Weaver (1953) (Eocene) – Massive, yellow - weathering arkosic sandstone.
- Tvh - Vine Hill Sandstone of Weaver (1953) (Paleocene) -- Glauconitic sandstone.

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SURFACE GEOLOGY
Figure 4.11-1

Eight (8) borings that were drilled by Raymond Concrete Pile Company in 1962 and 1963 (Frederic R. Harris, Inc., 1964) along the Shell Terminal provided more detail of the subsurface conditions. These borings were spaced along the Shell Terminal wharf alignment. The boring depth ranged from approximately Elevation -95 to -135 feet MLLW. These borings were part of the design plan set for the Shell Terminal and there was no accompanying geotechnical report available for review.

The borings logs showed that subsurface conditions were reasonably uniform along the planned Shell Terminal wharf alignment. The mudline elevation as reported on the boring logs ranged from approximately Elevation -32 feet to -41 feet. Young bay mud (very soft to firm silty clay) was encountered at each boring and ranged from about 32 to 41 feet thick depending upon location. Medium dense to dense mostly granular soils (alluvium) including fine to coarse sand and sand with gravel were found beneath the young bay mud, to the bottom of the borings. In two borings there was an appreciable thickness of stiff to very stiff silty clay found between the surficial young bay mud and the deeper granular alluvium. In some borings there were occasional lenses of more cohesive material within the granular alluvium.

Bedrock was apparently not encountered in these borings, although during drilling and sampling it is sometimes difficult to discern the difference between dense alluvium and the uppermost highly weathered bedrock of the Franciscan formation. It is likely that the top of bedrock is located slightly deeper than approximately Elevation -135 feet. Based on the topography and surface geology of the area to the south and east of the site, it is likely that bedrock would be encountered at slightly higher elevation beneath the shoreward portion of the trestle structure (at the Project's southernmost limit).

Figures 4.11-2 and 4.11-3 are reproductions of the boring locations and logs, taken from the original design plan set (Frederic R. Harris, 1964). Figure 4.11-2 also shows 5-foot bathymetric contours for the site, including the trestle area.

A recent detailed hydrographic survey and associated bathymetric map (Sea Surveyor, 2004) provides the top elevation of the mudline in the area surrounding the Shell Terminal wharf and a portion of the trestle. Review of the data shows that the mudline elevation at the eight boring locations has changed over time. On the north side of the wharf (Berths #1 and #2) where active mooring/berthing and/or dredging occurs, the mudline in 2004 was about the same or slightly lower than it was in 1962/1963. At boring number 4, located on the landward side of the Shell Terminal wharf (Berth #3), the mudline elevation has significantly increased. Comparison of the recent 2004 hydrographic survey data with the mudline contours on the original plan set from 1964 clearly show that significant deposition of sediment has occurred on the landward side of the Shell Terminal wharf.

Figure 4.11-2 – Boring Logs

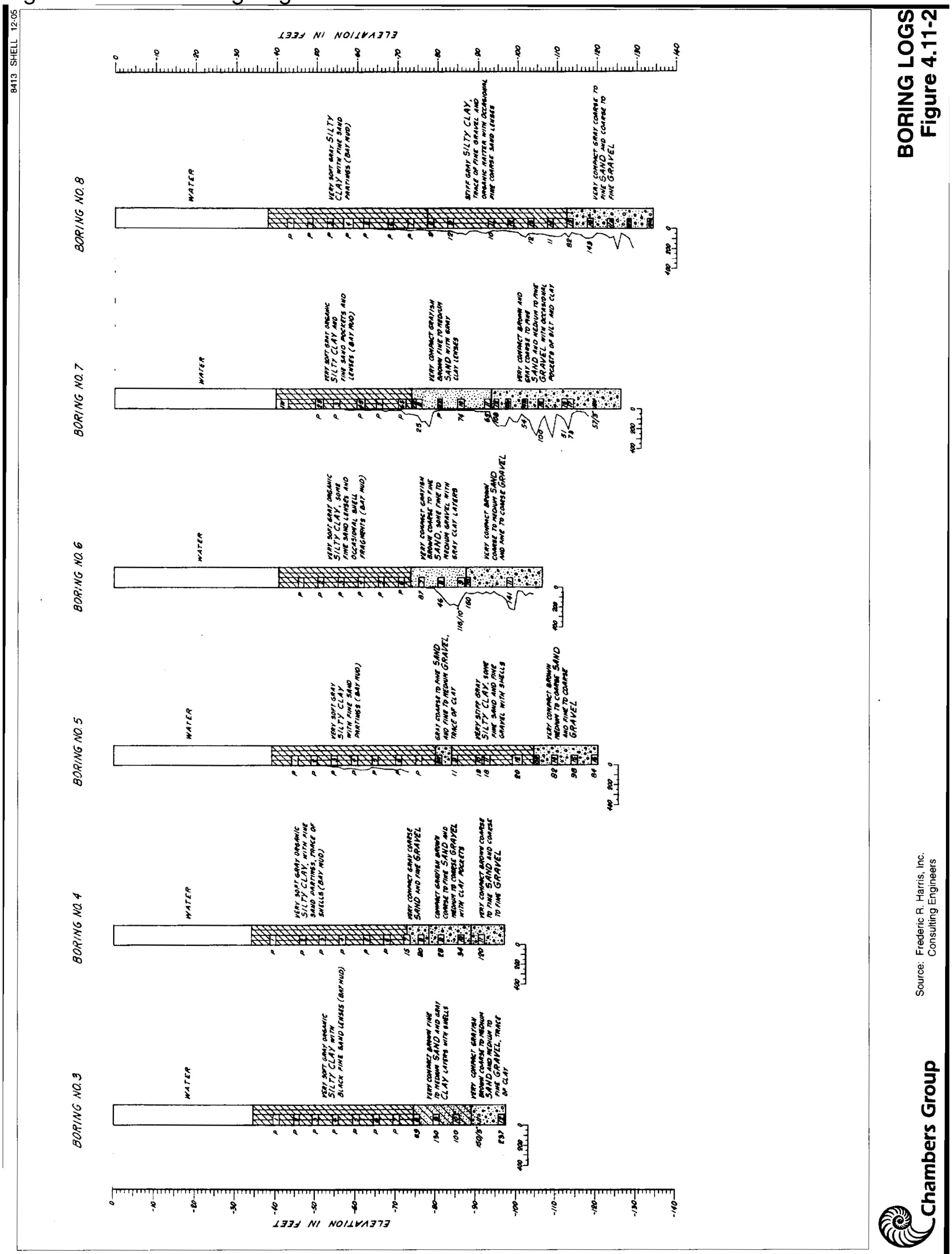
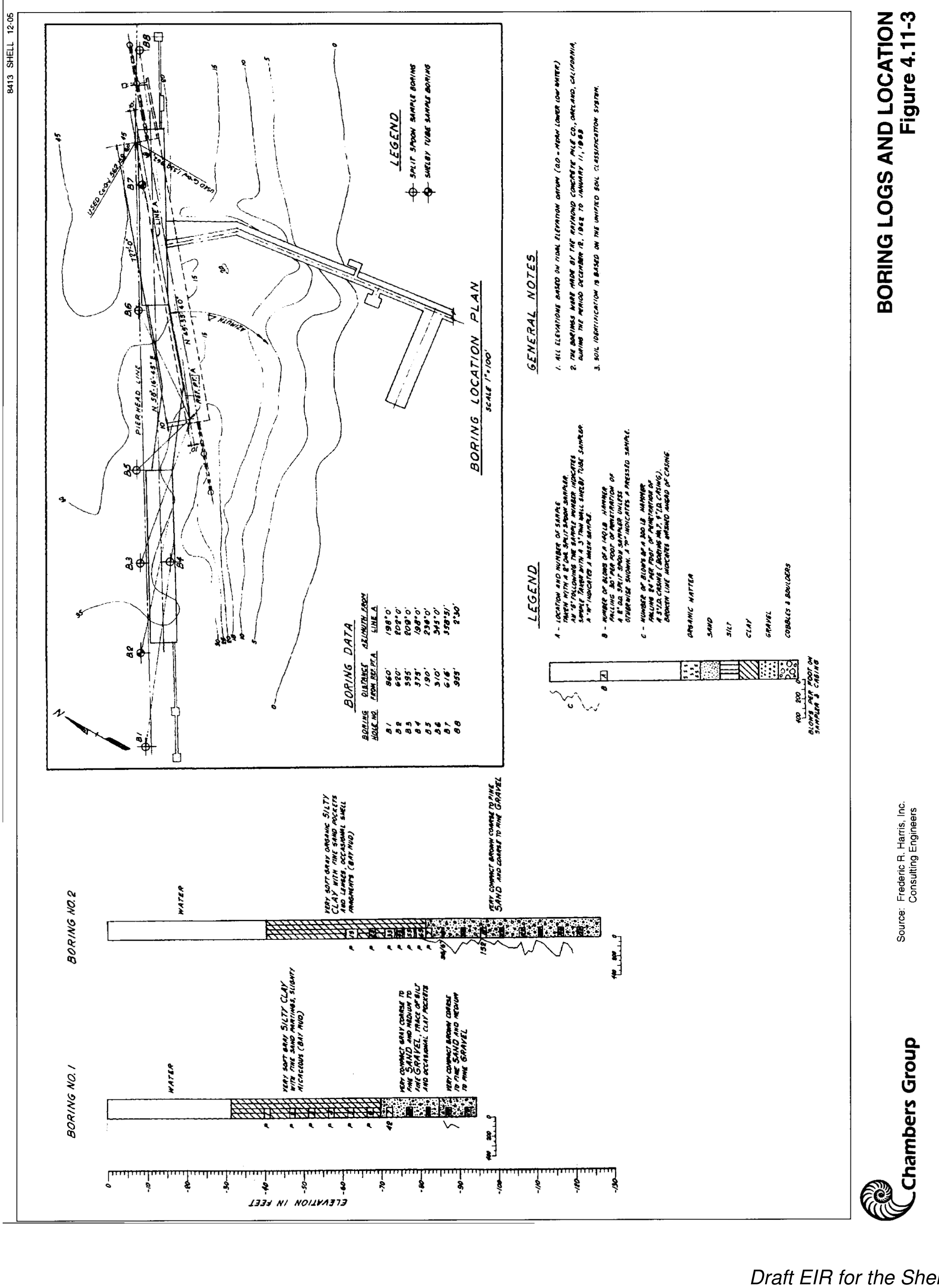


Figure 4.11-3 – Boring Logs and Location



Site-specific geotechnical data help clarify the site conditions and associated considerations in several respects:

- Along the Shell Terminal wharf alignment, there is still relatively thick young bay mud after the berth area was placed into service and operated. Thus, lateral pile capacity would still be significantly influenced and governed today by the presence of young bay mud. Note that the significant number of battered piles in the foundation system provides lateral capacity and restraint by transferring some portion of the overall lateral loading into axial loading.

- Along the Shell Terminal wharf alignment, granular layers beginning at about Elevation -70 feet and below could potentially reduce lateral pile capacity and increase downdrag forces should liquefaction occur during strong seismic shaking. Based on the information from the boring logs, including Standard Penetration Test blow count data (the industry standard) it appears that these deeper granular soils are reasonably dense and/or contain sufficient fines (mostly silt and some clay) such that liquefaction potential would be generally low and should any liquefaction occur it would be very localized. However, no current industry standard liquefaction analysis has been conducted.

At locations along the Shell Terminal wharf there are significant differences in elevation of young bay mud from the back side (Berths #3 and #4) to front side (Berths #1 and #2) of the wharf (estimated slopes of approximately 20 to 25 degrees in some places based on current 2004 bathymetric data), slope movement of the uppermost portion of the young bay mud could occur during seismic shaking. Lateral movement or spreading would induce additional lateral forces on piles (in addition to the loss of lateral capacity). The fact that the young bay mud slope across the Shell Terminal wharf has apparently remained relatively stable over a long period of time, i.e., no evidence that mass movements have occurred, suggests that this slope is stable under static loading conditions (and also under propeller wash conditions associated with mooring vessels). Note that the apparent long-term average slope angle of about 20 degrees cited above is generally steeper than would normally be found in “unrestrained or confined” young bay mud. It is likely that the wharf pile system is providing lateral restraint and/or support to the young bay mud mass.

- The trestle portion of the Shell Terminal likely is underlain by young bay mud that is thick enough to affect pile design and behavior, although it is also possible that the mud thins out in the shoreward direction. Thus, lateral behavior of the trestle piles is most likely influenced and may be governed by the presence of the young bay mud.

- The variation in soil conditions across this fairly large site could result in spatial variations in the magnitude and timing of ground response during seismic shaking, which could then result in similar variations in the structural response of the wharf and trestle.

Regional Seismicity

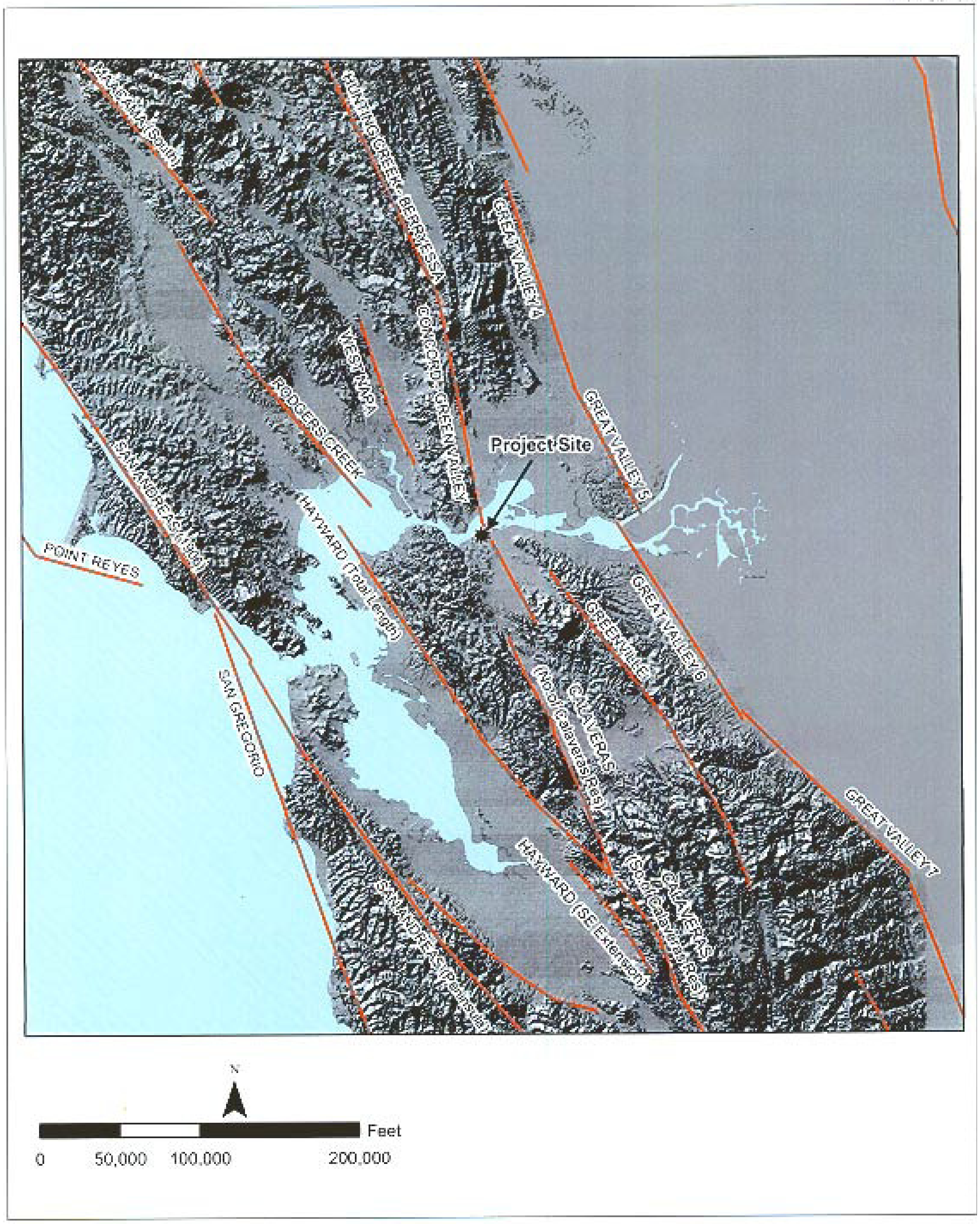
The San Francisco Bay region lies along a major, seismically active plate boundary. The San Andreas Fault, which forms the boundary between the Pacific and North America tectonic plates, has produced numerous earthquakes in the Bay Area during historic and prehistoric times. Movement between the plates has created several other active faults parallel to the San Andreas, including the Hayward, Calaveras, Greenville, Concord/Green Valley, Rodgers Creek, and San Gregorio Faults. These faults create a zone of faulting approximately 50 miles wide through the greater San Francisco Bay Area. These faults and other faults that are close to the site are shown on Figure 4.11-4. The approximate distance from the site, estimated moment Mw for earthquakes along the faults, and estimated slip rates of the faults are summarized in Table 4.11-1.

Table 4.11-1
Known Active Faults in Site Vicinity

Fault	Approximate Distance from Site (miles)	Estimated Maximum Magnitude (Mw)	Slip Rate (mm/year)	Approximate Recurrence Interval (years)
Concord/Green Valley	2.5	6.9	6	200
Greenville	19.1	6.9	2	620
West Napa	11.0	6.9	1	700
Calaveras (north)	16.2	6.8	6	180
Hayward	11.6	7.1	9	160
Rodgers Creek	11.6	7.0	9	200
Great Valley (seg. 4 to 6)	15.1 to 18.7	6.5 to 6.7	1.5	475 to 625
Hunting Creek	29.3	7.1	6	200
San Andreas	29.6	7.9	24	220
San Gregorio	32.2	7.6	5	450
Point Reyes	37.6	7.0	0.3	3500
Monte Vista	41.6	6.7	0.4	2400
Calaveras (south)	44.2	6.2	15	35
Maacama (south)	48.4	6.9	9	220
Note: Fault parameters were adapted from Cao et al (2002) and WGCEP (2003)				

Several major historic earthquakes have occurred within the Bay Area on several of the major faults. A major earthquake occurred in 1836 and 1868 along the Hayward Fault, which is located approximately 12 miles from the site. Both earthquakes had estimated magnitudes of around Mw = 7. The Working Group on California Earthquake Probabilities (WGCEP) (2003) estimated there is a 62 percent chance that there will be a major damaging earthquake in the San Francisco Bay Area within the next 30 years (Mw = 6.7 or greater), and a 27 percent chance of a magnitude 6.7 or greater earthquake on the Hayward/Rodgers Creek fault zone within the next 30 years.

Figure 4.11-4 – Regional Fault Map



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Source: California Division of Mines and Geology (California Geological Survey)

REGIONAL FAULT MAP
Figure 4.11-4

Another major earthquake occurred in 1861 on the Calaveras fault, which is located approximately 16 miles south of the site. This earthquake caused surface rupture for 8 miles through San Ramon Valley and caused severe damage within Contra Costa County. Major earthquakes on San Andreas Fault can also cause significant ground shaking with high potential for damage to structures. The 1838, 1906 (estimated Mw = 7.9), and 1989 (Mw = 7.1) earthquakes on the San Andreas Fault are the major earthquakes that have occurred in the past 200 years. The 1906 and 1989 (Loma Prieta) earthquakes caused major damage to structures in the Bay Area. Estimated Mw of future earthquakes for various strands of the San Andreas in the Bay Area vary from about Mw 7.0 to 7.9 (WGCEP, 2003). The “Mare Island” earthquake of 1898, along the southern end of the Rodgers Creek Fault, which is approximately 12 miles from the Shell Terminal, is also of historic significance. Toppozada et al. (1986) believe that the earthquake epicenter was located near the southern end of the fault, and the estimated Mw was 6.2.

Site-Specific Seismicity

The Shell Terminal is surrounded by Concord/Green Valley Fault on the east, West Napa and Rodgers Creek faults on the northwest, Hayward fault on the west, and Calaveras fault on the south as shown on Figure 4.11-4.

The Concord/Green Valley fault is located less than 3 miles away from the site and is believed to be able to produce an Mw 6.9 earthquake about every 200 years. Although in the 150-year history no major earthquake has been recorded on this fault, the Working Group on Northern California Earthquake Probabilities (2003) inferred that the entire Concord/Green Valley fault zone could rupture in one major event. There is concern that the ruptures might occur beneath Suisun Bay.

Several other faults are located about 10 to 20 miles from the site, and each of these is believed to be able to produce large earthquakes with a range of Mw 6.5 to about 7.0.

Active faults, as defined by the California Geological Survey (Hart and Bryant 1997), do not transect the Shell Terminal. An active fault, as defined in the Alquist-Priolo Earthquake Fault Zoning Act, is one that has had surface displacement within Holocene time (about the last 11,000 years). The purpose of the Alquist-Priolo Act is to regulate development near active faults to mitigate the hazard of surface rupture (Hart and Bryant 1997).

Several inactive faults or pre-quaternary active faults (over 2 million years old), including the Southampton and Franklin Faults, are within several miles of the site. The Southampton Fault is located approximately 2 miles west of the site, and the Franklin Fault is located approximately 4 miles west of the site. The Franklin Fault is believed to be the northern extension of the active Calaveras Fault.

The CGS (2002) developed Probabilistic Seismic Hazard Maps showing expected levels of ground shaking in the form of Peak Ground Acceleration (PGA). Seismic shaking maps are prepared using consensus information on historical earthquakes, faults, and geologic materials. Historic earthquakes, areas damaged, the slip rates of major faults, and geologic materials were combined to calculate the shaking hazard at peak ground acceleration, spectral acceleration for 0.3-second period, and spectral acceleration for 1.0-second period. The shaking hazard maps show the level of ground motion that has 1 chance in 475 of being exceeded each year, which is equal to a 10 percent probability of being exceeded in 50 years. For the Shell Terminal area, this expected PGA value is approximately 0.46 g.

The Caltrans (1996) California Seismic Hazard Map also shows contours of peak acceleration. These contours reflect Maximum Credible Events (MCEs) for the various contributing faults, and apply to ground motions for rock or stiff soil. In the vicinity of the Shell Terminal, the map shows a peak acceleration contour of 0.5 g.

Both of these sources provide data which implies that strong ground shaking is likely should a major earthquake on a nearby active fault occur.

Tsunamis

Tsunamis are sea waves typically created by undersea fault movement or coastal or subsea landslide. Tsunamis may be generated at great distance from shore (far field events) or nearby (near field events). Waves are formed, as the displaced water moves to regain equilibrium, and radiates across the open ocean, similar to ripples from a rock being thrown into a pond. When the waveform reaches the coastline, it pushes upward from the ocean bottom to create a high swell of water that breaks and washes inland with velocities as high as 15 to 20 knots. The water mass, as well as vessels, vehicles, or other objects in its path create tremendous forces as they impact coastal structures.

Tsunamis have affected the coastline along the Pacific Northwest during historic times. The Fort Point tide gauge in San Francisco recorded approximately 21 tsunamis between 1854 and 1964. The 1964 Alaska earthquake generated a recorded wave height of 7.4 feet and drowned several people in Crescent City, California. In the case of a far-field event, the Bay area would have hours of warning; for a near-field event, there may be only a few minutes of warning, if any.

A tsunami originating in the Pacific Ocean would lose much of its energy passing through San Francisco Bay. Ritter and Dupre (1972) estimated runup for the 100-year return period tsunami near the Golden Gate to be 10 feet, which may be regarded as a reasonable maximum for future events. The available data indicate a systematic diminishment of the wave height from the Golden Gate to the head of the Carquinez Strait and on into Suisun Bay. The MOTEMS (codified as the CCR), 2001 Title 24 Part 2, California Building Code, Chapter 31F (Marine Oil Terminals) section 3103F.5.7 (Table 31F-3-8) provides estimated tsunami run-up for areas of California. The maximum expected increment of wave height in the western part of the Carquinez Strait to the west of the Shell Terminal for the 100-year return period event is estimated to be 3.3 feet, and for the 500-year return period event is estimated to be 4.0 feet. These values are to be added to the maximum high tide heights to determine potential damage.

A recent study prepared for the CSLC (Borrero, Dengler, et. al. (In prep), investigated the effects of a tsunami wave at marine oil terminals inside of San Francisco Bay. The results indicate that wave heights at the Carquinez Strait are on the order of 25 percent of the values at Richmond, and 10 percent of the values at the Golden Gate of those presented by Ritter and Dupre (1972) and in the MOTEMS. The areas near the terminals in the Carquinez Strait show a much more muted response to the waves entering the Golden Gate. Based on this new study, both far field and near field events would be attenuated at the Shell Terminal to less than one foot positive/negative wave heights. Based on these new analyses, it is anticipated that the 2001 Title 24, Part 2 California Building Code, Chapter 31F, Table 31-3-8 will be modified (personal communication, Martin Eskijian 2005).

4.11.1.2 Shell Terminal Structure

Shell Terminal Description

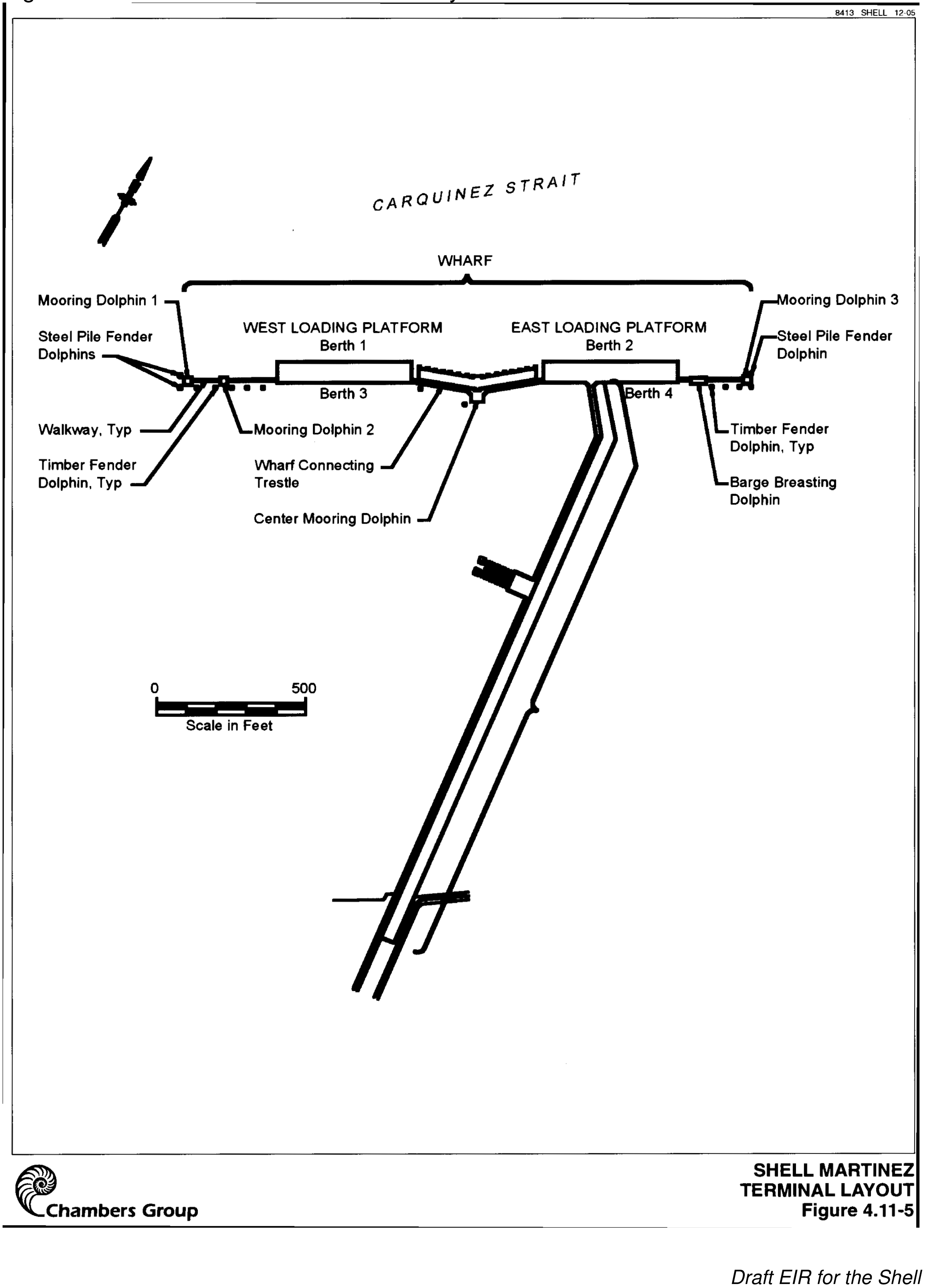
The Shell Terminal consists of a 1,900 foot long by 56 foot wide timber approach trestle that provides access to a 1,950 foot long concrete wharf. The Shell Terminal wharf and trestle are shown on Figure 4.11-5. The approach trestle provides a 16 foot wide roadway and 40 foot wide pipeline corridor. The trestle has a north-south orientation and connects into the Shell Terminal wharf's east side loading platform.

The Shell Terminal was built in 1964 and replaced the earlier terminal built around 1915 (Shell Oil Company 1964). Two tanker berths are located on the outboard side of the Shell Terminal wharf (Berths #1 and #2). Two barge berths are located in the shallower protected area on the inboard side of the wharf, Berth #3 to the west and Berth #4 to the east. The mudline at the tanker berths is generally below -40 MLLW. The mudline in the barge berths is as high as -5.5 MLLW (Sea Surveyor Inc. 2004). The barge berths do not appear to be in use as the water depth is insufficient for fuel loading operations. The top of deck elevation of the wharf is 15.67 MLLW.

Loading Platforms and Connecting Trestle

Oil is transferred at two 450 feet long by 70 foot wide (inside of fenders) loading platforms. Tankers berth against the heavy steel frame/wood faced fender racks on the north (outboard) side of the loading platforms. Barges berth against lighter steel frame/wood faced fender racks on the south (inboard) sides of the loading platforms and are moored to the loading platforms. Tanker mooring lines are run to 100-ton bollards along the face of the tanker berths and barge mooring lines run to 30-ton cleats along the face of the barge berths.

Figure 4.11-5 – Shell Martinez Terminal Layout



Petroleum products are offloaded from vessels at each loading platform by hoses. The hoses are supported by 40-foot high steel hose handling structures that frame into the deck of the loading platforms. A small crane sits atop each hose handling structure for manipulating hoses to the vessels. A pipe manifold and valve system is located at the base of the structure.

The loading platforms are constructed of precast concrete girders and caps connected together by cast-in-place closure and fill concrete. Each loading platform is supported by 160 20-inch square plumb and batter prestressed concrete piles. The plans indicate that the 20-inch square prestressed piles have 60-ton compression capacity. All batter piles are inclined at 1 horizontal to 3 vertical. The top of the deck is at elevation +15.67 MLLW.

The loading platforms are joined together by the Shell Terminal Connecting Trestle which is 475 feet long by 50 feet wide. At the center of the Connecting Trestle is the Center (mooring) Dolphin which also supports the operations building and a small boat dock. The Wharf Connecting Trestle and Center Dolphin are constructed from precast concrete girders and caps connected together by cast-in-place closure and fill concrete. A total of 111 20-inch square prestressed piles support the Wharf Connecting Trestle/Center Dolphin. The piles are both plumb and batter. The Center Dolphin is fitted with two double 50-ton quick release hooks for tanker mooring lines.

Mooring/Breasting Dolphins

There are four mooring dolphins and one barge breasting/mooring dolphin. Mooring Dolphins 1 and 2 are at the west side of the Shell Terminal wharf. Mooring Dolphin 3 and the Barge Breasting Dolphin are located at the east side of the Shell Terminal wharf. All of the dolphins are fitted with double 50-ton quick release mooring hooks. The Barge Breasting Dolphin has a fender system for barges berthing and mooring at Berth #4.

All of the dolphins are of similar construction with a six-foot deep cast-in-place pile cap. Each mooring dolphin is supported by twenty-one 20-inch square prestressed piles. The barge breasting dolphin is supported by twenty-five 20-inch square prestressed piles. The piles are both plumb and batter. The original Mooring Dolphin 1 was destroyed during a barge collision and rebuilt in 2001 (Eschelon Engineering 2001).

Fender Dolphins

There are a number of steel and timber fender dolphins. Two steel pile fender dolphins protect the west end of the Shell Terminal wharf and two steel pile fender dolphins protect the east end of the wharf from vessel impact. The original fender dolphins at the west end of the wharf were destroyed by the 2001 barge collision and subsequently rebuilt. Eight timber fender pile dolphins protect the mooring dolphins and walkways at the inboard berths. These dolphins are placed somewhat differently than shown on the 1964 plans (Shell Oil Company 1964).

Walkways

Walkways provide access to the mooring and barge breasting dolphins from the loading platforms. There are a total of 10 walkway spans. The walkways are 5 foot wide simple span prestressed concrete bridge planks with spans varying from 35 feet to 45 feet. The westernmost span was destroyed by the 2001 barge collision and subsequently rebuilt. Each of the pile bents are constructed from 20-inch square batter prestressed concrete piles framing into cast-in-place bent caps.

Approach Trestle

The trestle was originally constructed in 1915 and modified in the 1950s or early 1960s to its present configuration. The 1915 trestle was a 3-pile bent structure and has been incorporated in the present roadway. This was expanded by the addition of 2 rows of piles to the east and further modified to tie into the present wharf, which was built in 1964 (Shell Oil Company 1993). Extensive repairs have been performed on the trestle over the years to maintain structural integrity (Agi International 1994). Detailed drawings and a history of the trestle are not available. The water depth is generally quite shallow – especially at the landside where the water recedes completely during low tide. At the outboard end where the trestle ties into the wharf, the mudline is at about -6 feet MLLW. The roadway elevation is approximately 11.6 feet MLLW.

The trestle is of heavy timber construction including piles, pile caps, braces, stringers and deck planks. There are a total of 858 piles supporting the roadway and pipelines. The piles are creosote or pressure treated. Eight of the piles are wrapped with a PVC sheath (Echelon Engineering, Inc. 2004). Piles from the older construction epochs have been encased in concrete to a foot or so below mudline on the landward portion of the trestle. Pile spacing along the bents is about 10 feet and bent spacing is estimated at 13.5 feet. The majority of the bents have 5 piles which frame into 12 by 12 timber bent caps. Many bent caps have been sistered by through bolting for the trestle expansion. Lateral bracing is a mixture of sag rods and heavy timber with some batter piles in the deeper water. The roadway section of the trestle is framed with 3 by 12 stringers spaced 2 feet on center and 3 by decking. No information was available to ascertain the age of the piles, pilecaps, braces or stringers.

The trestle supports vehicles and pipelines. Signs posted on the trestle limit vehicle loads to 4 tons. The trestle is heavily loaded by 18 product pipelines as well as additional utility and electrical lines. There are pipeline vertical expansion loops at three locations and it is anticipated that loads to the trestle are very high at these locations. Because there are no loading evaluations available for analysis in this Draft EIR, it is unknown at this time if the trestle is performing adequately for the vertical loads from numerous product lines.

Structural Condition

Loading Platforms, Connecting Trestle, Dolphins and Walkways

The most recent inspection of the Shell Terminal wharf and fender dolphins available for review was performed in 1993 (MacDonnell Engineering 1991). At that time the fender system at Berth #1 was found to be in good condition as were all the wharf and dolphin structures and piles. Some timber on the fender racks needed replacement. No problems were noted with the piles, caps, decks or appurtenances.

The most recent inspection of the wharf and fender dolphins available for review was performed in 2001 (Eschelon Engineering 2001). The inspection found the facility condition to vary from fair to good. The majority of the prestressed concrete piles were undamaged or contained only small cracks. Twenty piles out of a total of 532 prestressed concrete piles had moderate damage including significant cracks, spalls and reinforcement corrosion. The steel fender racks were in good condition. The concrete superstructure or deck system was found to be in good condition however some isolated areas of damage or concrete deterioration were found.

A reconnaissance survey to observe the condition of the loading platforms, Shell Terminal wharf connecting trestle, mooring dolphins, breasting dolphin, fender dolphins and approach trestle was performed for this Draft EIR (Moffatt & Nichol 2005). The loading platforms, connecting trestle and center mooring dolphin appeared to be in good condition from the waterside. A couple of problems were noted on the topsides and fenders. The timber facing on the fender racks had broken away at several locations due to tanker berthing. There is some deck cracking indicating corrosion of the reinforcing steel. Some of the mooring appurtenance concrete support pedestals are cracked indicating reinforcing steel corrosion.

The mooring and breasting dolphins are generally in good condition. However some problems were noted. The decks are cracked due to corrosion of reinforcing steel. The vertical face and soffit edges of the outer mooring dolphins are spalling due to corrosion of the reinforcing steel. Mooring Dolphin 3 has a large spall at the top of one pile. Also, several of the walkway supports are cracked.

The two steel fender dolphins on the west end of the wharf appear to be in good condition. The steel fender dolphin on the east end moves perceptibly during ambient wave loading implying it is either in soft soil or has been hit.

The decks of two of the walkways have exposed reinforcing due to corrosion. These problems for the most part are probably due to lack of concrete cover and consequent chloride attack of the reinforcing steel.

Approach Trestle

The approach trestle has been inspected numerous times (MacDonnell Engineering 1993; Agi International 1994; Echelon Engineering, Inc. 2004). The timber piles have generally been found to be in fair to good condition. Similarly, the pile caps have been found to be in fair to good condition. A roadway deck replacement has just been completed including replacement of deteriorated stringers. The inspection reports did not provide load capacity calculations. The trestle is posted for 4-ton vehicle load, so it is likely that some vertical load calculations exist.

Several potential problems were noted during the reconnaissance observation. A significant number of the 858 piles are quite old. These old piles appear to have been encased in concrete. Experience has shown that wood tends to rot at the concrete interface and this is a potential weakness. Build-ups have been spliced on some of the older piles using through bolts and sistered timbers. Some pile caps are warped and checked. Due to splicing of pile caps for the trestle widening, many of the caps are not level and heavy loads are carried by through bolting putting high demand on the connections. A section of the west side vehicle railing is leaning outward due to loads imposed by some hung-off lines.

The trestle is laterally braced in several different ways. Sag rods have been installed between the landside concrete encased piles. In deeper water some heavy timber braces have been employed. In still other locations, some batter piles provide lateral bracing. The sag rods appeared to be in good condition. Some of the timber braces were severely deteriorated due to attack from marine organisms. The condition of the batter piles is unknown.

Structural Adequacy

This terminal will be required to satisfy the MOTEMS criteria (see Section 4.11.2, Regulatory Setting), which describe three risk categories. The terminal will likely fall into the high risk category due to the large number and length of product pipelines. The high risk category has several implications including a requirement to resist severe seismic loadings (more severe than lower risk categories).

Loading Platforms, Connecting Trestle, Dolphins and Walkways

The structural adequacy for environmental and operational loadings is only partly known. The Shell Terminal wharf system (loading platforms, connecting trestle, dolphins and walkways) is partially described in the construction documents (Frederic R. Harris Inc. 1964). A 1992 mooring analysis was done to permit larger vessels (146,000 dwt) than the original design (33,000 dwt) (MacDonnell Engineering 2004). A recent mooring analysis indicates that the Shell Terminal wharf is adequate for mooring loads due to a 211,000 dwt tanker at Berths #1 and #2 (Shell Oil Products

2005). It is not clear if modifications are required to the Shell Terminal wharf for the increased vessel size. No information was provided for the seismic or berthing capacity of the Shell Terminal wharf.

The loading platforms and connecting trestle and mooring dolphins utilize batter piles which are efficient for resisting predictable, moderate lateral loads such as those due to ship mooring and berthing. Batter piles, however, are known to perform poorly during seismic events where the high stiffness tends to result in higher acceleration levels. No seismic analysis of the Shell terminal has been provided and it is unknown whether the loading platforms, connecting trestle and mooring dolphins are adequate for the seismic event required by MOTEMS. Based on the type of construction and seismic environment, it is likely that some elements of the Shell Terminal wharf such as batter pile to pile cap connections will be severely damaged during a major seismic event.

The fender system absorbs vessel berthing energy by compressing. The berthing energy increases in proportion to vessel mass. In the process of absorbing energy by compressing, lateral berthing loads are transmitted through the fender system into the deck of the loading platforms and ultimately resisted by axial forces in the batter piles and plumb piles. Larger vessels, such as described in the previous paragraph, will result in higher berthing forces than originally envisioned. Modifications to the fendering system may have been done to address these forces. No berthing analyses have been provided and it is unclear if the loading platform and fender system are adequate for the MOTEMS berthing loads due to the larger vessels.

The walkways rest on short seats at the mooring dolphins and loading platforms. In the event of a major earthquake, a walkway could conceivably slip off the short seat. Also, the deck deterioration, left uncorrected, will eventually weaken the walkways.

Approach Trestle

Some of the caps are in questionable condition. It is not clear whether the lateral bracing system is adequate. Because there are no loading evaluations available for analysis in this Draft EIR, it is unknown at this time if the trestle is performing adequately for the vertical loads from numerous product lines.

Considering the age, condition and framing issues previously described, a major earthquake may result in significant damage to the piles bents and subsequent loss of support for the pipelines.

4.11.2 Regulatory Setting

The laws and regulations regarding soils and geologic conditions that would apply to the proposed Project were addressed in Section 4.2, Water Quality, and Section 4.3, Biological Resources. For the structures, the CSLC's MOTEMS has recently been codified as CCR Title 24, Part 2, Chapter 31F (Marine Oil Terminals). This part of the California Building Code became effective on February 6, 2006. The requirements of

MOTEMS generally represent the best current practice of industry and meet the standards of the “best achievable protection of public health and safety and the environment” prescribed by Section 8755 of the Public Resources Code.

MOTEMS requires that:

a. All MOTs must have an above-the-water engineering audit every 3 years.

b. For high risk MOTs (as defined in the MOTEMS), the operator has 30 months from from February 6, 2006 (MOTEMS effective date) to perform the first engineering “audit”. This audit is due August 2008. The audit requires an underwater inspection, thorough above water inspection and an extensive walk-through to verify compliance with MOTEMS including a seismic analysis, mooring analysis and other assessments. In order to remain MOTEMS compliant, if future activities involve larger vessels, higher impact velocities, or structural degradation, etc., the MOT will analyze and update the pertinent structural, mooring, pipeline and other operational parameters as prescribed by the MOTEMS.

4.11.3 Impact Significance Criteria

Earthquakes can cause major damage to marine structures. Damage may be eliminated or minimized if seismic analysis/design has been incorporated into the criteria and structural design. Impacts are considered adverse and significant if any of the following conditions apply:

- Significant erosion of the soils at the mudline such that there is loss of lateral pile capacity;

- Settlement of the soil beneath the Shell Terminal wharf’s foundation that could substantially damage structural components of the wharf

- Ground motion due to a seismic event that could induce liquefaction, underwater slope instability and lateral spreading, settlement, or a tsunami (primarily vessel impact) that could damage structural components of the Shell Terminal wharf;

- Deterioration of structural components of the Shell Terminal wharf due to corrosion, weathering, fatigue, marine organisms, overload, accidents or erosion that could reduce structural capacity, which could then fail to meet performance requirements;

- Increase in the structural dead load (affecting the seismic analysis), vessel size, or a change in a mooring configuration (mooring/berthing issues) that might exceed the existing structural capacity of the Shell Terminal, and thus reduce the structural integrity; and;

- Damage to petroleum pipelines and/or valves along the pipeways from any of the above conditions that could release crude/product into the environment.

4.11.4 Impact Analysis and Mitigation Measures

4.11.4.1 Geotechnical Conditions of the Shell Terminal

Impact GEO-1: Ground Rupture

The Shell Terminal is not located in the Alquist-Priolo Earthquake Fault Zone. Surface rupture from known active faults is not anticipated, and impacts would be adverse, but less than significant (Class III).

The Shell Terminal wharf and trestle lie outside of the Alquist-Priolo earthquake fault zone and surface rupture from known active faults is not anticipated. Impacts would be adverse, but less than significant (Class III). Per MOTEMS, high risk MOTs have 30 months (from February 6, 2006) to perform the first engineering “audit” which will be due August 2008. Part of the requirement is a seismic analysis.

<u>GEO-1: No mitigation is required</u>.

Impact GEO-2: Groundshaking and Seismically Induced Landslides

The impact of berth dredging, natural scour or accumulation of soil in steep slopes near or adjacent to Shell Terminal wharf piles should be considered in soil-structure interaction. In addition, lateral spreading (downslope movement) resulting from any moderate earthquake may result in damage to the Terminal. Shell is required to comply with MOTEMS, and impacts are adverse, but less than significant (Class III).

The Shell Terminal wharf and trestle are located within a seismically active area with several faults capable of inducing strong ground shaking. Such shaking would result in associated shaking of the structures, including interaction between the soil and structural foundations.

The bathymetry surrounding the Shell Terminal is characterized by accumulation of soft sediments in the areas landward of the Shell Terminal wharf (Berths #3 and #4), while the water depth on the waterside of the Shell Terminal wharf (Berths #1 and #2) is maintained to accommodate sufficient ship draft for mooring/berthing tankers. As such, there is a relatively steep slope (for young bay mud type sediments) from behind the Shell Terminal wharf to the berthing areas in front. While this slope, which is likely to be buttressed by the presence of the Shell Terminal wharf piles, appears to be statically stable over long time periods, lateral spreading of soils (downslope movement) at or near the ground surface caused by ground shaking is possible. Therefore, lateral spreading or downslope movement resulting from any moderate earthquake may result in Terminal damage, and should be considered and analyzed in soil-structure interaction evaluation.

The Shell Terminal is required to comply with the MOTEMS that became effective February 6, 2006, with the first engineering audit due for completion in August 2008. As this is a regulatory requirement, impacts are considered less than significant. As part of MOTEMS requirements, studies would determine whether lateral spreading (downslope movement) caused by groundshaking would cause any loss of lateral support on the structure, and/or induce a significant lateral load on the foundation system. The required evaluations will identify corrections needed to ensure structural integrity.

GEO-2: No mitigation is required.

Impact GEO-3: Liquefaction and Seismically Induced Settlement

The site has not had a current industry standard liquefaction evaluation performed. As such, the potential for impacts from seismically induced settlement are unknown. Because Shell is required to comply with MOTEMS, impacts are adverse, but less than significant (Class III).

Liquefaction is a phenomenon whereby insufficiently dense saturated granular soil temporarily loses strength and bearing capacity during and immediately following seismic shaking. Loose, clean sand at relatively shallow depths (low overburden or confining pressures) is most susceptible to liquefaction. If the granular soil is unconfined or poorly confined and on a slope, it tends to spread or flow. Liquefaction usually results in volume reduction that is manifested in ground settlement. Most of the sand from this site appears to be older Pleistocene age sand that is medium dense to dense, based on limited data.

There is no information on any liquefaction evaluation that was conducted to current standards for the Shell Terminal. If sand liquefies it could result in volume changes that in turn could result in soil settlement and downdrag on the piles, as well as temporary reduction in lateral support to the Shell Terminal wharf foundation system. Liquefaction also could result in lateral movement as stated above in Impact GEO-2. Because the site does not have an industry standard liquefaction evaluation, the potential for impacts from seismically induced settlement would be considered significant adverse (Class II) impacts.

The Shell Terminal is required to comply with the MOTEMS that became effective February 6, 2006, with the first required engineering audit due August 2008. As this is a regulatory requirement, impacts are considered less than significant. As part of MOTEMS requirements, a liquefaction assessment is required. This evaluation would identify corrections needed to ensure structural integrity.

GEO-3: No mitigation is required.

Impact GEO-4: Tsunami

Tsunamis would attenuate to minimal wave heights at the Shell Terminal, and impacts are considered adverse, but less than significant (Class III).

A tsunami originating in the Pacific Ocean would lose most of its energy at it passes through San Francisco Bay and into Carqinez Strait. A far field tsunami generated 8.5 foot wave height at the Golden Gate would attenuate to 3.14 feet near Richmond, and further attenuate to approximately 1 foot near the Shell Terminal. A near field tsunami generated 1.96 foot wave height at the Golden Gate, would attenuate to less than one foot near Richmond, and further attenuate to approximately 3 inches near the Shell Terminal. Because the waves are predicted to be so minimal, vessels are not required to release from their moorings and/or move away from the berths. No damage would be expected to occur to either the berth or vessel, and impacts are less than significant (Class III). Additionally, because floating debris may be a result of tsunami damage from other locations, it is safer for a vessel to remain moored to the Shell Terminal berth.

A seiche is a standing-wave oscillation of the surface of water in an enclosed basin, such as a bay or lake. A seiche can vary in period and in height from several centimeters to a few meters, and can be initiated by local atmospheric changes aided by winds, tidal currents, or an earthquake. At least one seiche occurred in the Bay in 1941, generated by gale force winds. The likelihood of a seiche occurring within the Carquinez Strait that could exceed the maximum wave height for the Shell Terminal wharf is uncertain but very unlikely. The impact of a seiche on the wharf is considered adverse, but less than significant (Class III).

Shell is required to comply with MOTEMS berthing and mooring criteria by August 2008. A mooring analysis would determine if the existing mooring system on the Shell Terminal wharf is in compliance with the MOTEMS requirements, and would identify any needed corrections

GEO-4: .No mitigation is required.

4.11.4.2 Structural Integrity Analysis

Impact GEO-5: Structural Damage or Failure of the Shell Terminal Structures Due to a Major Earthquake

No documentation was received indicating that the Shell Terminal structures have been analyzed for the maximum credible earthquake as specified by the MOTEMS criteria. Consequently, the impacts of a major earthquake on the Shell Terminal are unknown. Because Shell is required to comply with MOTEMS, impacts are adverse, but less than significant (Class III).

The Shell Terminal can be thought of as two different types of structures – the newer Shell Terminal wharf structures and the older approach trestle. It appears that neither of these has been evaluated for the forces or displacements arising from a major earthquake as specified by the MOTEMS criteria. The type of construction (batter piles) has not historically performed well in major earthquakes. A failure in the piling system could result in loss of support with consequent damage or collapse.

The potential for damage or failure to the trestle is considered to be greater than the capability of the wharf structure. The trestle piles and pile caps have probably never been analyzed, nor are capable of resisting forces from a major earthquake. Failure of the trestle piles and bents would result in loss of support for the pipelines.

Shell is required to comply with MOTEMS structural criteria, which include evaluation of the structures and their foundations. For high risk MOTs, including the Shell Terminal, the operator has 30 months (from February 6, 2006) to perform the first engineering "audit", a part of which includes a seismic analysis. This audit is due in August 2008. Required evaluations will identify deficiencies and identify needed corrections.

GEO-5: No mitigation is required.

Impact GEO-6: Structural Damage to the Loading Platforms Due to Berthing of the Larger Vessels

No analysis has been provided for berthing larger vessels at the Shell Terminal. Berthing of larger vessels may overload the fender system and overload the piling. Overloading the piling may result in cracking at the cap, separation of piles from the cap or failure of the piles. Consequently, the impacts of a berthing accident are unknown. Because Shell is required to comply with MOTEMS, impacts are adverse, but less than significant (Class III).

The loading platforms were designed for a much smaller vessel than the 211,000 dwt vessel described in the Shell operating manual. No berthing analysis has been provided for this size or other larger vessels. No data was provided during the analysis to know whether modifications have been made to the Shell Terminal to berth the larger vessels. A failure in the piling system due to a berthing accident could result in loss of support with consequent damage or collapse.

Shell is required to comply with MOTEMS structural criteria which includes evaluation of the structures and their foundations. For high risk MOTs, the operator has 30 months (from February 6, 2006) to perform the first engineering "audit", a part of which includes a seismic analysis. This audit is due in August 2008. Required evaluations will identify deficiencies and identify needed corrections.

GEO-6: No mitigation is required.

4.11.5 Impacts of Alternatives

Impact GEO-7: No Project Alternative

Removal, abandonment, or other decommissioning of the Shell Terminal (wharf and trestle) would result in no geotechnical impacts and would eliminate long-term potential for structural damage to the Shell Terminal (Class IV).

Under the No Project Alternative, Shell's lease would not be renewed and the existing Shell Terminal would be subsequently decommissioned with its components abandoned in place, removed, or a combination thereof. The decommissioning of the Shell Terminal would follow an Abandonment and Restoration Plan as described in Section 3.3.1, No Project Alternative.

Under the No Project Alternative, alternative means of crude oil/product transportation would need to be in place prior to decommissioning of the Shell Terminal, or the operation of the Shell Refinery would cease production, at least temporarily. It is more likely, however, that under the No Project Alternative, Shell would pursue alternative means of traditional crude oil transportation, such as a pipeline transportation, or use of a different marine terminal. Accordingly, this Draft EIR describes and analyzes the potential environmental impacts of these alternatives. For the purposes of this Draft EIR, it has been assumed that the No Project Alternative would result in a decommissioning schedule that would consider implementation of one of the described transportation alternatives. Any future crude oil or product transportation alternative would be the subject of a subsequent application to the CSLC and other agencies having jurisdiction, depending on the proposed alternative.

Removal of the structure could result in a temporary disturbance to sediment as discussed in Section 4.2, Water Quality, but there would be no geotechnical impacts.

Following decommissioning of the Shell Terminal there would be no potential for structural damage that could result to the Shell Terminal, approach trestle and pipelines, and subsequent pipeline spills and a beneficial impact (Class IV) would result. The No Project Alternative would result in Shell operations transferred to other Bay Area marine terminals. Those terminals would have the potential for geologic and structural impacts depending on the specific condition or need for modifications or new construction associated with each terminal.

<u>GEO-7: No mitigation is required</u>.

Impact GEO-8: Full Throughput Alternative

Use of existing marine oil terminals would have no adverse impacts. Pipeline connections to the Shell Refinery would have potential (Class II) impacts.

Other area marine oil terminals are subject to the same general geologic and seismic conditions, as the Shell Terminal. Each terminal would be required to fully comply with MOTEMS by their respective owners. As such, impacts are considered adverse, but less than significant (Class III).

Modification of existing and new overland pipelines would be required to deliver crude/ product to the Shell Refinery. Shell would likely own/have responsibility for pipeline integrity. Overland pipelines require appropriate engineering of alignments and proper selection of valves and flanges to assure that impacts are minimized. Still, damage to pipelines by seismic displacement or other hazards can result in significant adverse impacts (Class II).

Pipelines are typically flexible enough to withstand strong ground shaking without rupturing. Special design or flexible connections need to be considered for areas where pipelines cross active faults and at connecting points to valves and storage facilities. Integrity review of pipelines is required by MOTEMS, and impacts are considered adverse, but less than significant (Class III). However, leaks from pipelines can be caused by seismic displacement, improper engineering design, corrosion, joint failure, and vandalism, which have the potential to result in significant, adverse impacts to other resources. Discussion of the consequences of spills is presented in Section 4.1, Operational Safety/Risk of Accidents, Section 4.2, Water Quality, Section 4.3, Biological Resources, Section 4.5, Land Use and Section 4.9, Visual Resources.

<u>Mitigation Measures for GEO-8</u>:

GEO-8. Damage to pipelines by seismic displacement or other hazards can be minimized by evaluating proposed routes and providing proper engineering design. Periodic inspection, maintenance, and retrofitting of pipelines shall also be conducted to reduce the possibility of pipeline failure due to corrosion and fatigue.

<u>Rationale for Mitigation</u>: Pipelines are typically flexible enough to withstand strong ground shaking and displacement, without failure. Special design or flexible connections need to be considered for areas where pipelines cross active faults and at connecting points to valves and storage facilities. With proper design for maximum seismic displacement, along with periodic maintenance and inspection, any significant, adverse impacts due to groundshaking would reduce the impact of pipeline rupture. Ensuring pipeline integrity reduces the potential for leaks or spills of oil. Periodic maintenance and inspection can also reduce the potential for leaks caused by corrosion and joint failure. Discussion of the consequences of spills is presented in Section 4.1, Operational Safety/Risk of Accidents. Implementation of the mitigation measures would reduce impacts to less than significant.

4.11.6 Cumulative Projects Impacts Analysis

Impact CUM-GEO-1: Impacts of Seismic Forces on Cumulative Marine Terminal Facilities

Wharves and trestles are designed to withstand large lateral forces, thus are not expected to have significant damage from most earthquake events. Cumulatively, if many pipelines were to rupture and leak oil or product significant adverse impacts to the surrounding environment (Class I or II) could occur. All marine oil terminals are required to comply with MOTEMS as of February 6, 2006, as such impacts are adverse, but less than significant (Class III).

The shoreline of San Francisco Bay, Carquinez Strait and Suisun Bay is home to many marine and industrial facilities that are susceptible to earthquake-related damage. The 1989 Loma Prieta earthquake caused extensive damage to various structures in the city of Oakland and its port facilities (Benuska 1991; Borchardt 1991). Liquefaction and seismically induced settlement of loose and soft soils caused most of the damage, which included failure of bridge supports and damage to storage tanks. Most wharves, constructed as highly redundant structures, experienced little or no damage during this earthquake. Wharves constructed to withstand large lateral forces are not expected to result in significant impacts during an earthquake, and compliance with MOTEMS is required, as such impacts are adverse, but less than significant (Class III). However, ruptured pipelines and storage tanks could release oil or product that could result in significant adverse impacts to the surrounding environment. Impacts are discussed in Section 4.2, Water Quality, Section 4.3, Biological Resources, Section 4.5, Land Use and Section 4.9, Visual Resources. Shell contributes incrementally to these impacts.

GEO- CUM-GEO-1: No mitigation is required.

Table 4.11-2
Summary of Geological/Structural Integrity
Impacts and Mitigation Measures

Impacts	Mitigation Measures
GEO-1: Ground Rupture	**GEO-1:** No mitigation required.
GEO-2: Groundshaking and Seismically Induced Landslides	**GEO-2:** No mitigation required.
GEO-3: Liquefaction and Seismically Induced Settlement	**GEO-3:** No mitigation required..
GEO-4: Tsunami	**GEO-4a:** No mitigation required.
GEO-5: Structural Damage to the Shell Terminal Wharf or Trestle due to a Major Earthquake	**GEO-5:** No mitigation required.
GEO-6: Structural Damage to the Shell Terminal Due to Berthing of larger vessels	**GEO-6:** No mitigation required.
GEO-7: No Project Alternative	**GEO-7:** No mitigation required.
GEO-8: Full Throughput Alternative	**GEO-8:** Apply engineering design, inspection, maintenance, and retrofitting of pipelines.
CUM-GEO-1: Impacts of Seismic Forces on Cumulative Wharf Facilities.	**CUM-GEO-1:** No mitigation required.

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